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Oat Fish Ready-to-Eat Product Enriched with Fish Protein Concentrate to Improve Nutritional Value

Endah Rochmatika[1]*, Mira Dian Naufalina[2], Raden Hilman Wirayudha[3], Wildan Zahrul Faqih[3], Usman Nugroho[1]

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ABSTRACT

The development of high-fiber oat-based products can be innovated by adding fish protein concentrate (FPC) to create healthy snacks. The application of ribbon fish FPC remains underexplored. This study aims to evaluate the use of ribbon fish FPC combined with oats to create food products. The optimal product formulation for nutritional characteristics was determined through a hedonic test to measure consumer preference. The research method used a Completely Randomized Design in the manufacture of FPC and oat fish products. The best FPC extraction results from the extraction frequencies (one, two, three times) were selected as fortification ingredients. Variations in the treatment of adding FPC to products with concentrations of 0%, 10%, 20%, and 30%. Nutritional composition testing uses the AOAC method for food analysis, including ash content using dry ashing, protein using the Kjeldahl method, fat using Soxhlet extraction, and carbohydrate content calculated based on the difference. The results of the study showed that the best ribbon fish FPC contained high protein (82.40%) with low fat content (1.15%) with a frequency of three extractions. The hedonic test on the product showed that 20% FPC (P2) obtained the highest score for the analysis of nutritional value in 100 grams, which has the potential to provide an efficient low-calorie satiety effect (321.24 kcal), high protein (22.75 g), sufficient dietary fiber (5.64 g), and low sugar (1.39 g). The use of local fishery resources is a potential raw material for food product diversification.

Keywords: nutrition, oat, protein, ribbon fish, snack

INTRODUCTION

Ribbonfish is a fish with economic value that produces abundant fish catches on the coast of South Java (Sakina *et al.* 2022; Hariyanto *et al.* 2022). Ribbonfish has the characteristics of a demersal fish originating from the Indian Ocean, which frequently experiences upwelling zones with high biological productivity as a fishery resource (Rochmatika *et al.* 2023). One of the marine species that is a primary target for fishermen (Phuryandri *et al.* 2020). Ribbonfish has an elongated body shape, silver color, and delicious and savory meat flavor (Abdurrahman *et al.* 2022; Rahmawanti *et al.* 2024). However, the highly perishable nature of fishery commodities triggers a decline in the quality of fresh fish, necessitating the processing of functional products (Wirayudha *et al.* 2022).

[1] Department of Bio-Entrepreneurship, Faculty of Economics and Business, Muhammadiyah Institute of Health Business and Technology, Tulungagung 66229, Indonesia
[2] Department of Nutrition, Faculty of Agriculture, Universitas Tidar, Magelang 56114, Indonesia
[3] Department of Nutrition, Faculty of Health Sciences, Muhammadiyah Institute of Health Business and Technology, Tulungagung 66229, Indonesia
* Corresponding Author:
Email: endahrochmatika89@gmail.com

Fish is a food source with a high protein content that can increase the nutritional value of protein for humans (Ayudiarti *et al.* 2021). Fish protein concentrate (FPC) is a food ingredient produced through a process that separates water and fat to achieve a higher protein content than the original (Putri *et al.* 2022; Pandiangan *et al.* 2024). The Indonesian Ministry of Health explained in 2018 that fresh ribbonfish contains up to 18 g of protein per 100 g. This makes it a suitable raw material for FPC, which is rich in protein and high in omega-3 fatty acids. The utilization of ribbonfish FPC has not been widely implemented, thus presenting an opportunity as a fortification ingredient in food products. Furthermore, the addition of FPC can affect sensory characteristics, including taste and aroma, which can influence consumer acceptance. This can be developed into innovation and creation of fishery products to increase the nutritional value of fish protein concentrate (Loppies *et al.* 2021).

Oat (wheat) based product development, as part of the cereal group, offers numerous antioxidants, including avenanthramides, selenium, phenols, and vitamins A, C, and E, and is high in dietary fiber (Sava *et al.* 2023). Meanwhile, protein concentrate derived from ribbonfish contains abundant macrominerals (potassium, sodium, phosphorus, and calcium) and amino acids, with an optimal proportion of essential amino acids for human nutrition. Its lipids are rich in polyunsaturated fatty acids (PUFAs), with the highest contributions from EPA and DHA (Wang *et al.* 2022). Development of ready-to-eat snacks made from oats enriched with ribbon fish protein concentrate, called Oat Fish as the name of the product development. Oat Fish products can be an alternative high-protein snack to increase nutritional intake that can be consumed by all groups, from children to the elderly.

This product is expected to provide health benefits because it contains essential nutrients needed by the body. The development of this ready-to-eat Oat Fish product offers a delicious and nutritious snack that can be consumed by people of all ages and social strata. The research aims to determine the best FPC with the extraction method as a fortification material for food products, determine the formulation of Oat Fish products according to consumer preferences with hedonic tests, and identify the nutritional value of selected product. Therefore, this study aims to identify the nutritional and sensory characteristics of oat-based snacks enriched with FPC and determine the optimal formulation.

METHODS

This research was carried out from July to August 2025 at the Laboratory of the Faculty of Fisheries and Marine Sciences, Airlangga University, Surabaya. This research was conducted in two stages, namely the production of ribbon fish FPC and the development and evaluation of products enriched with FPC. This research was conducted in two stages: the production of ribbon fish FPC and the development of FPC-enriched products. FPC production used a completely randomized design with independent treatments for extraction frequency (one, two, and three times). Product production also used a completely randomized design, consisting of four treatments with three replications. The independent variable was the best FPC addition to the product, namely 0%, 10%, 20%, and 30%. Furthermore, the best product from the hedonic test results was analyzed for nutritional value.

Production of Ribbon Fish Protein Concentrate

The resulting ribbon fish FPC refers to the method of Soemadi *et al.* (2024) for the production of catfish FPC and Wirayudha *et al.* (2026) for the production of mackerel scad FPC. Fresh ribbon fish (Trichiurus lepturus) were gutted, skinned, deboned, and thoroughly washed to obtain clean fish meat. The fish meat was then boiled at 100°C for 15 minutes, drained, and pressed using a cotton cloth to remove excess water. Fish protein concentrate (FPC) was prepared through solvent extraction using isopropyl alcohol (IPA) with a fish-to-solvent ratio of 1:3 (w/v). The extraction process was carried out at different extraction frequencies (1, 2, and 3 extraction cycles), with fresh solvent replacement every 30 minutes. After each extraction cycle, the mixture was filtered to separate the solid residue from the filtrate. The solid residue obtained from the previous extraction was then extracted again until the specified extraction frequency was reached. The extracted residue was then dried in a hot air oven at 60°C for 20 hours. The dried material was ground using a food processor and sieved through a 60-mesh sieve to obtain a uniform FPC powder. The resulting FPC samples were then evaluated for nutritional quality to determine the optimal extraction treatment. Proximate analysis, including protein, fat, moisture, and ash content, was performed according to standard analytical methods, while carbohydrate content was calculated based on the difference.

Production of Oat Fish Product Enriched Ribbon Fish Protein Concentrate

The product formulations in this study are presented in Table 1. Different levels of ribbon fish protein concentrate were included to evaluate their effects on the nutritional and sensory properties of the final product. Proximate analysis of FPC was carried out using laboratory instruments in accordance with standard analytical procedures with 3 replications. Nutritional composition testing uses the AOAC method which consists of ash content using dry ashing, protein using the Kjeldahl method, fat using Soxhlet extraction, and carbohydrate content calculated based on the difference. The product composition includes oats, ribbon fish FPC, seaweed, salt, eggs, plain yogurt, and sesame oil, which are then made into a solid dough and oven-baked until cooked.

Nutritional value analysis was determined using the best-performing formulation from the hedonic test. Furthermore, sensory testing was carried out with a

Table 1 Formulations of oat fish product with different concentrations of ribbonfish FPC

Material	Formulation (gr)			
	F0	F1	F2	F3
Ribbonfish FPC	0	10	20	30
Rolled oat	80	70	60	50
Plain yogurt	5	5	5	5
Dried seaweed	4	4	4	4
Egg	5	5	5	5
Sesame oil	3	3	3	3
Mushroom broth	2	2	2	2
Salt	1	1	1	1
Total	100	100	100	100

hedonic assessment by 30 untrained panelists to determine product acceptance. Sensory evaluation was carried out using the hedonic method (Kusuma & Herawati 2023). Organoleptic data, including appearance, taste, aroma, and texture, were analyzed using analysis of variance (ANOVA) with SPSS version 25. Furthermore, a Tukey post hoc test was performed to identify significant differences between treatments. Oat Fish products were subjected to hedonic testing by 30 untrained panelists, with parameters such as color, aroma, taste, texture, and appearance, using a scoring test with a scale of 1-5. The assessment scores include 5 (Very Like), 4 (Like), 3 (Neutral/Quite Like), 2 (Dislike), 1 (Very Dislike).

The Nutritional value is calculated based on the wet weight per 100 g of product, which includes protein, fat, water, and ash, which are measured experimentally through proximate analysis, while carbohydrate content is calculated based on the difference using the difference method. Energy value was calculated using the Atwater conversion factor, which is 4 kcal/g for protein and carbohydrates and 9 kcal/g for fat. Then, the nutritional content was converted to a 30 g serving size and compared to commercial snack bars.

RESULTS AND DISCUSSION

Physicochemical Properties of Ribbonfish FPC for Product Development

Ribbonfish fish protein concentrate (FPC) represents an unprecedented research opportunity, therefore, the results section needs to be described. The best FPC produced is then added to the product formulation, the resulting product is sensory evaluated to assess its acceptability based on consumer preferences. The formulation product with the highest panelist acceptance was selected for nutritional analysis of the final product composition based on wet weight, including moisture, ash, protein, fat, carbohydrate, and dietary fiber content.

Testing of the best FPC from three times extraction treatments using isopropyl alcohol solution. The estimated composition of ribbonfish FPC is presented in Table 1. The resulting protein content is 82.40% which exceeds the minimum protein content requirement of 70% set by the Indonesian National Standard for fish protein concentrate (SNI 01-4273-1996). These findings indicate that FPC meets the national quality requirements for Type A fish protein concentrate. Its high protein content has the potential to be a raw material for the development of protein-enriched food products and fish protein-based industries.

Using the same method, ribbonfish FPC yields were higher than catfish FPC (Soemadi *et al.* 2024) but lower than scad mackerel (Wirayudha *et al.* 2026). This difference in protein content may be influenced by the type of fish, as marine fish generally produce concentrates with higher protein content than freshwater fish (Junianto *et al.* 2021). The proximate composition of ribbonfish FPC is presented in Table 2. These physicochemical characteristics are important because they influence the nutritional quality and potential application of FPC in Oat Fish formulation.

The results of the ribbonfish FPC study showed a fat content of 1.15%, indicating efficient lipid removal during solvent extraction. This value is below the 3% threshold for FPC type B according to FAO (1986). Meanwhile, the relatively low moisture of 6.27% is a good indicator. The maximum moisture of 10% is categorized as the quality standard for class 1 fishmeal as outlined in SNI No. 01-2175-2002. If the moisture is higher, it can accelerate bacterial growth and increase susceptibility to spoilage (Liur 2020). The low moisture in this study was influenced by the duration of extraction and the large amount of water evaporation (Rahmasari *et al.* 2023).

The ash content of 2.34% indicates no excessive mineral contamination. Julyaningsih *et al.* (2023) explained that the ash content of snakehead fish protein concentrate was below the critical threshold of 10%, within acceptable limits. The carbohydrate content of FPC was 7.93%, which is thought to originate from non-protein components remaining after the extraction process. The yield obtained was approximately 21.03% of the initial raw material weight. This decrease was influenced by an increase in the number of washing cycles, which reduced the final FPC yield. This decrease was also related to a decrease in fat and moisture and the influence of drying temperature (Rieuwpassa *et al.* 2020).

Sensory Evaluation of Oat Fish Made with Fish Protein Concentrate

The quality characterization of products regulated in SNI is based on the five human senses: color/appearance (eyes), texture (skin), aroma (nose), taste (tongue) (Sholehah & Hafiludin 2022; Lamusu 2018). The sensory evaluation results showed that the

Table 2 Physicochemical characteristics of selected ribbonfish fish protein concentrate (FPC) for product development

Parameter (%)	Ribbonfish FPC (values ± SD)	Mackerel scad FPC	Catfish FPC
Ash	2.34 ± 0.04	1.32	0.67
Moisture	6.27 ± 0.84	3.69	5.34
Protein	82.40 ± 0.19	93.50	83.10
Fat Content	1.08 ± 0.10	0.42	0.20
Carbohydrate (by difference)	7.93 ± 1.17	1.08	10.69

addition of ribbonfish protein concentrate significantly affected the taste, aroma, and texture of the Oat Fish product ($p < 0.05$), while the color was not significantly affected by the different formulations. Among the treatments, P2 (20% FPC) achieved the highest average scores for taste (3.57 ± 0.86), aroma (3.80 ± 0.85), and texture (3.57 ± 0.90), indicating the highest consumer acceptance. Although P3 contained higher levels of FPC, its sensory scores were slightly lower than P2, indicating that excessive addition of FPC may reduce product acceptability. Therefore, formulation P2 was considered the optimal formulation based on the sensory evaluation. Table 3 presents the mean hedonic scores for the sensory attributes of product, including color, aroma, taste, texture, and overall acceptability, as evaluated by the panelists.

According to Kumoro *et al.* (2022), color is a physical characteristic that strongly influences consumer acceptance. The results of the hedonic test showed that the addition of ribbon fish FPC at various concentrations did not significantly affect the color of Oat Fish ($p > 0.05$). Panelists' preference scores ranged from 3.40-3.53, with the highest score for formulation P3 (30% FPC). This indicates that the addition of FPC up to 30% was still acceptable to the panelists and did not cause significant color changes in the final product. Figure 1 presents the Oat Fish products with the addition of protein concentrate at various concentrations.

Meanwhile, taste is an important parameter, as illustrated in Table 3. The addition of FPC significantly affected the panelists' preference for the Oat Fish product flavor ($p < 0.05$). Formulation P2 (20% FPC) obtained the highest score of 3.57 ± 0.86 and was significantly different compared to P0. Increasing the FPC concentration to 20% was thought to improve the product's flavor, while adding up to 30% tended to decrease the panelists' acceptance level, possibly due to the increasingly dominant fish flavor. Savory taste is a sensation perceived by the taste buds, formed through the combination of ingredients and their compositions in a food product (Fadlilah *et al.* 2024). The protein in fish breaks down into peptide fragments and free amino acids that interact directly with receptors on the tongue, resulting in the perception of a combination of savory (umami), sweet, and bitter flavors (Khotimah *et al.* 2024; Immaroh *et al.* 2025).

The hedonic test results showed that the addition of FPC significantly affected the aroma of Oat Fish ($p < 0.05$). Formulation P2 had the highest aroma score of 3.80 ± 0.85, while P0 obtained the lowest score of 2.83 ± 0.99. These results indicate that the addition of FPC at the right concentration can improve the aroma characteristics of the product, but too high an addition tends to reduce the level of panelists' preference due to the stronger fish aroma. Aroma evaluation is crucial because it can quickly indicate whether a food product is perceived as appetizing (Morquecho-Campos *et al.* 2020).

The addition of FPC significantly affected the texture of Oat Fish ($p < 0.05$). Formulation P2 achieved the highest texture score of 3.57 ± 0.90, while P0 had the lowest score of 2.87 ± 0.86. This indicates that the addition of FPC up to 20% can improve the texture characteristics of the product, while increasing the concentration to 30% does not further increase the level of panelist acceptance. This addition of protein can form a more stable matrix, resulting in a preferred texture when bitten and creating the expected crunchy texture sensation of the product (Nawaz *et al.* 2021). The decrease in the level of preference in treatment P3 (30% FPC) may be caused by the addition of too high

Table 3 Hedonic scores of oat fish products formulated with different levels of ribbonfish fish protein concentrate (FPC)

Parameter	Treatment			
	P0 (0%)	P1 (10%)	P2 (20%)	P3 (30%)
Color	3.40 ± 1.003^{a}	3.47 ± 0.937^{a}	3.50 ± 1.009^{a}	3.53 ± 0.819^{a}
Taste	2.87 ± 0.937^{a}	3.03 ± 0.999^{ab}	3.57 ± 0.858^{b}	3.30 ± 0.794^{ab}
Aroma	2.83 ± 0.986^{a}	3.17 ± 0.913^{a}	3.80 ± 0.847^{b}	3.33 ± 0.994^{ab}
Texture	2.87 ± 0.860^{a}	3.20 ± 0.847^{ab}	3.57 ± 0.898^{b}	3.30 ± 0.794^{ab}

Note: Values are presented as mean ± standard deviation. Different superscript letters in the same row indicate significant differences between formulations ($p < 0.05$)

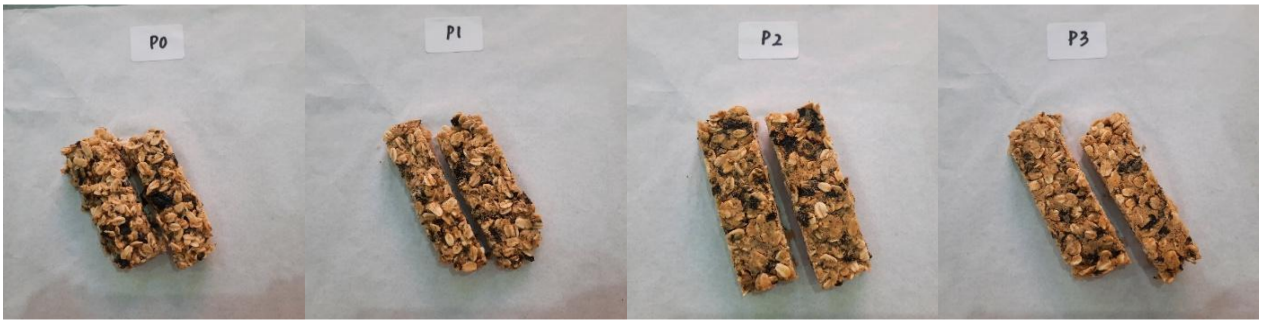

Figure 1 Oat Fish product with the addition of fish protein concentrate (FPC) at various concentrations. P0 = 0% FPC, P1 = 10% FPC, P2 = 20% FPC, P3 = 30% FPC.

a protein concentration, which can increase the dough's ability to bind water. This can cause the final product to have a denser texture, making it less preferred (Qiu *et al.* 2024).

Nutritional Adequacy Analysis of the Best Oat Fish Product

The nutritional composition of the Oat Fish formulation was selected based on the hedonic test with the addition of 20% ribbonfish FPC. The reported values represent the nutritional characteristics of the final product. Protein, fat, water, and ash contents were determined experimentally through proximate analysis of the Oat Fish, while carbohydrate content was calculated by difference. Total energy values were estimated using the Atwater conversion factor (protein and carbohydrate 4 kcal g^{-1} and fat 9 kcal g^{-1}). The results are presented in Table 4 and represent the nutritional characteristics of the final product, providing information on its potential as a high-protein and nutrient-rich snack.

The chemical characteristics of Oat Fish products are compared with commercial soy-based cereal and snack bar products on the market. Based on the conversion results per 100 grams of material, Oat Fish shows a significantly higher protein density of 22.75 g, while the average commercial snack bar only ranges from 8-16 g. This significant increase in protein content is a positive contribution from the use of fish meat as a source of high-quality animal protein. In addition, Oat Fish is able to reduce total carbohydrates to 9.06 g, which is below the minimum carbohydrate standard for commercial snack bars (12-21 g). The combination of low carbohydrate content and 5.64 g of dietary fiber can help increase satiety by slowing down the digestive process, suggesting that Oat Fish can be a nutritious food choice with efficient energy contribution (Leszczyńska *et al.* 2023).

The high protein content of Oat Fish products (22.75 g/100 g) is higher than snack bars made from peanuts and sweet potato flour. This is influenced by the use of ribbonfish FPC (82.40%) which has a high protein content, thus contributing to an increase in total energy per serving (Patmawati *et al.* 2022). The effectiveness of ribbonfish FPC as a fortification ingredient is seen in its ability to increase protein levels compared to without the addition of fish-based ingredients. This indicates that FPC can be used as a substitute for wheat flour in product formulations and nutritional supplementation (Cassol *et al.* 2024). The dietary fiber content of 5.64 g/100 g comes from the oat raw material in the formulation. Oats are known to contain β-glucans which contribute to increased dietary fiber intake (Hartanti & Ilmi 2025). The combination of ingredients in the product formulation is a source of protein and dietary fiber. In addition to beta-glucans, wheat also provides a large number of other bioactive compounds such as phenolic acids, tocopherols, sterols, avenanosides, and avenanthramides (Paudel *et al.* 2021).

The relatively low total sugar content, at 1.39 g/100 g, indicates that the product has no added sugar. This refers to BPOM regulation No. 1 of 2022, which states that a total sugar content of no more than 5 g/100 g is considered a low-sugar food. Meanwhile, the product's sodium content is 123 mg/100 g, slightly exceeding the maximum limit for low sodium content of ≤120 mg/100 g (BPOM, 2022). This is due to the addition of salt and seasonings during the product formulation process. The water content is 33.18 g, indicating that the increased water content in the product is due to the high content of fish protein, which has ionic water-binding properties (Mardiyah *et al.* 2022). In comparison, snack bars fortified with eel flour have a water content of 3.47%-5.98% (Rasulu *et al.* 2021). The use of marine fish sourced from local areas also ensures the sustainability of food availability (Rochmatika *et al.* 2025). The comparison results show that Oat Fish has significant functional advantages, especially in energy efficiency and protein density.

CONCLUSION

The protein (82.40%) and fat (1.15%) content of FPC hairy tail produced using the 3-fold extraction method has the potential to be used as a food fortification ingredient. The addition of 20% FPC to healthy snack products shows the best level of consumer acceptance in terms of color, aroma, taste,

Table 4 Nutritional value of selected fish oat formulation (20% FPC) compared to commercial snacks

Nutrient	Value per 100 g	Value per 30 g serving	*Commercial Snack Bar (30 g)
Energy (kcal)	321.24	96.37	108–112.5
Protein (g)	22.75	6.83	1.5–7.2
Fat (g)	12.16	3.65	3–10
Saturated fat (g)	4.09		
Carbohydrate (g)	30.20	9.06	12–21
Total sugar (g)	1.39		
Dietary fiber (g)	5.64	1.69	1.2–4.8
Sodium (mg)	123		
Moisture (g)	33.18		
Ash (g)	1.71		

Source: *Asriasi & Anugrah 2020.

and texture. The nutritional value of oat fish products has a higher protein content (6.83 g), lower carbohydrates (9.06) compared to commercial protein snack bars (1.5-7.2 g), carbohydrates (12-21 g) so that they provide a satiating effect with efficient calories. Other functional advantages of oat fish products include low sugar (1.39 g/100 g), fiber from oats (β-glucan), and bioactives from wheat. This is an alternative healthy snack that supports local fish-based foods.

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